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Educational technology and human capital: a model and simulations

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Abstract

This paper develops a labor market model of educational technology-induced human capital, and demonstrates that the labor market for the vocational school graduates in Turkey is trapped into equilibria characterized by low levels of human capital and employment. First, we employ a stochastic equilibrium method so as to model and analyze the equiibria in question in the absence the effects of educational technology. We prepare and use a carefully-crafted questionnaire to collect data for the key endogenous variables and relations and estimate the main parameters of the model. Second, we incorporate the effects of educational technology into the model and undertake system dynamics simulations so as to demonstrate the extent to which educational technology utilization could help avoid the equilibria in question, leading to higher levels of human capital and employment.

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Keywords: Educational technology; Human capital; Social capital; Vocational school graduates; Labor market.

1. Introduction

Human capital is among the central, educational technology-related concepts that have persistently remained at the center of social inquiry in the last twenty years. As a central organizing concept, it refers to the "the knowledge, skills, competences and attributes embodied in individuals that facilitate the creation of personal,

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social and economic well being" (OECD, 2001:18). The extent to which educational technology plays a role in the formation of knowledge, skills, and competences in question is an issue we will take up in this paper.

The particular context where relations between educational technology and human capital will be examined in this paper involves the recent labor market for the vocational school graduates in Turkey.[2] Clearly, the job competences of graduates could be influenced by the prior technology-related educational methods involving, for instance, computerized learning practices in the school and in the workplace. Properly mastered software packages used for virtual undertaking of the tasks as well as estimation, projection and simulation of the processes required by the work are likely to be an integral component of effective job performance.

To theorize about the relations among the key variables involved, we will develop two interrelated sub-models, the first of which is presented in the second section which analyzes human capital in the absence of the effects of educational technology. The third section *presents* the empirical results. The fourth section extends the first model so as to incorporate the effects of educational technology and undertake system dynamics simulations. The concluding remarks follow in the fifth section.

2. The Model[3]

Consider a labor market where workers provide a labor service, say L, to firms. Let Q_t^{DL} denote the *quantity demanded* for service L supplied by workers, which indicates the quantity of labor firms are willing and able to hire at time t. Q_t^L depends on the price of labor at time t (w_t^1), prices of other inputs hired/used by firms at time t (w_t^i, i=2,…,m), human capital of workers at time t-1 (HK_{t-1}) and social capital[4] of workers at time t-1 (SK_{t-1})[5].

i.e., $Q_t^{DL} = f^D\ (w_t^1,\ldots, w_t^m, HK_{t-1}, SK_{t-1}),$

which is a labor demand function. $Q_t^{DL} \in (0,\infty)$. However, Q_t^{DL} is properly transformed so as to take values between 1 and 7. $w_t^1 \in (0,\infty)$, i = 1,…m. $HK_{t-1} \in [1,5]$, and $SK_{t-1} \in [1,5]$.

Let Q_t^{SL} denote the *quantity supplied* for service $L,$ which indicates the quantity of labor workers are willing and able to supply (sell) at time t. Suppose that Q_t^{SL} depends on the price of labor at time t (w_t^1), the human capital of workers at time t-1 as well as the social capital of workers at time t-1 (SK_{t-1}).

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[2] For an informative account of vocational education and training in Turkey in the context of European Qualifications Framework, see Borat (2005). Zaim (2009) provides an example of impact assessment for support to basic education in Turkey. Yılmaz (2009) points out a quality-centered problem of education and human capital (in relation to growth) in Turkey. For an example of a relatively different account of the relation between human capital and growth, see Tatoğlu (2011).

[3] This model is based on a revised version of Kara (2010), and benefits, in part, from Kara (2007a, 2007b, 2013) and Kara and Zaim (2012).

[4] Social capital refers to "the collection of resources owned by the members of individual's personal social network, which may become available to the individual as a result of the history of these relationships." (Gaag, 2005:20). There are a number of works in the literature, such as Boorman (1975), Reingold (1999), Allen (2000), Fernandez, Castilla and Moore (2000), Munshi (2003), Calvó-Armengol and Jackson (2004, 2007) and Yueh (2009) which explore the links between social networks and employment. There are also models in the literature, which examine the relations between social capital and growth. A subset of these models are presented by Chou (2005) who explores how "social capital impacts growth by assisting in the accumulation of human capital".

[5] Human capital and social capital affecting period t are acquired in t-1and are available at the beginning of t.

i.e., $Q_t^{SL} = f^S\,(w_t^1, HK_{t-1}, SK_{t-1}),$

which is a labor supply function.[6] Q_t^{SL} was rated on a scale with 1 representing the lowest score that can be assigned, and 7 representing the highest. Hence, $Q_t^{SL} \in [1,7]$.

For analytical purposes, we will assume that the labor demand and labor supply functions have the following explicit forms:

$$\ln Q_t^{DL} = \alpha_0 + \alpha_1 \ln HK_{t-1} + \alpha_2 \ln SK_{t-1} + \sum_{i=1}^{m} \delta_i \ln \omega_t^i + u_t$$

and

$$\ln Q_t^{SL} = \beta_0 + \beta_1 \ln HK_{t-1} + \beta_2 \ln SK_{t-1} + \gamma \ln w_t^1 + v_t$$

where u_t and v_t are independent normally distributed white noise stochastic terms uncorrelated over time. They have zero means and variances σ_u^2 and σ_v^2 respectively.

To theorize about the movements over time (i.e., the dynamic trajectory) of human capital, we will assume that the relative strength (or magnitude) of the labor demand compared to the supply provides an impetus for human capital to be adjusted upwards over time. Taking this assumption into account, we formulate the following adjustment dynamic for human capital.

$$HK_{t+1} / HK_t = (Q_t^{DL} / Q_t^{SL})^k ,$$

where k is the coefficient of adjustment. Taking the logarithmic transformation of both sides, we get:

$$\ln HK_{t+1} = \ln HK_t + k\,(\ln Q_t^{DL} - \ln Q_t^{SL}).$$

We will call this the dynamic adjustment equation. Substituting the functional expressions (forms) for $\ln Q_t^{DL}$ and $\ln Q_t^{SL}$ specified above, setting the values of SK_{t-1}, w_t^1, i=1,…,m, to their average values SK_{t-1}^{avr} , w_t^{iavr}, i=1,…,m and rearranging the terms in the equation, we get,

$$\ln HK_{t+1} - \ln HK_t + k(\beta_1 - \alpha_1) \ln HK_{t-1} = k(\alpha_0 + (\alpha_2 - \beta_2) \ln SK_{t-1}^{avr} + \sum_{i=1}^{m} \delta_i \ln \omega_t^{iavr} - \gamma \ln w_t^{1avr}) + k(u_t - v_t),$$

which is a second order stochastic difference equation, the solution of which, for the intertemporal equilibrium human capital, HK^* is as follows:

$$HK^* = \exp\left\{ \frac{k(\alpha_0 + (\alpha_2 - \beta_2)\ln SK_{t-1}^{avr} + \sum_{i=1}^{m} \delta_i \ln \omega_t^{iavr} - \gamma \ln \omega_t^{1avr})}{k(\beta_1 - \alpha_1)} + \right.$$

[6] The demand and supply equations could be obtained through appropriately formulated profit maximization and utility maximization problems, respectively.

$$+\frac{\lambda_1}{\lambda_1-\lambda_2}\sum_{j=0}^{\infty}\lambda_1^j z_{t-j}+\frac{\lambda_2}{\lambda_2-\lambda_1}\sum_{j=0}^{\infty}\lambda_2^j z_{t-j}\Bigg\}$$

where $z_t = k(u_t - v_t)$

$$\lambda_1\lambda_2 = k(\beta_1-\alpha_1)$$

$$\lambda_1+\lambda_2 = 1$$

In case where λ_1 and λ_2 are conjugate complex numbers, i.e., λ_1 , $\lambda_2 = h \pm vi$ = r(cos θ ± i sin θ), the intertemporal equilibrium human capital is:

$$HK^* = \exp\left\{\frac{\mathrm{k}(\alpha_0+(\alpha_2-\beta_2)\ln SK_{t-1}^{avr}+\sum_{i=1}^{m}\delta_i\ln\omega_t^{mavr}-\gamma\ln\omega_t^{1avr})}{k(\beta_1-\alpha_1)}+\right.$$

$$\left.+\sum_{j=0}^{\infty}r^j\frac{\sin\theta(j+1)}{\sin\theta}z_{t-j}\right\}$$

where r is the absolute value of the complex number, and sin θ = v/r and cosθ =h/r.

To study whether this intertemporal equilibrium human capital is high or low, and whether it remains stable over time, we need to empirically estimate the parameters involved. This is done in the next section.

3. Empirical Analysis[7]

3.1 The sample: Data for this study was gathered using a questionnaire including questions about labor demand, labor supply, wages, human capital and social capital of vocational school graduates in Turkey. The questionnaire was distributed to 500 labor market participants in 2007-2008. 391 questionnaires were returned. Most questions (item) were rated on a scale with 1 representing the lowest score that can be assigned, and 5 representing the highest.[8] The level of competence of the vocational school graduates, rated by the employers/firms will be taken to be a proxy for the human capital of the graduates. The degree of communication, coordination and cooperation/collaboration among the schools, graduates, firms and other partners in the vocational education and placement system and social networks, rated by the participants in the social networks in question, will be taken to be a proxy for the social capital of the graduates.

3.2 Estimation of the parameters:

(i) Labor demand: Because of the availability, at low wages, of new graduates of vocational schools as interns, the effect of their wages on their labor demand is negligible. Similarly, because of the low substitutability

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[7] The empirical work and estimations in this section benefit, in part, from Kara and Zaim (2007). The constructions of the sample, labor demand and labor supply functions as well as the derivation/presentation of the analytical results in this section follow the procedures (and, in part, wording) similar those of Kara (2007a, 2007b, 2010 and 2013).

[8] In some cases, the highest score was 7.

between new graduates' labor and other inputs, the effects of other input prices on the labor demand in question are negligible as well. Thus, input prices are left out of the labor demand function. We assume that minimal human capital and minimal social capital induce minimal quantity demanded for labor, i.e., if HK_{t-1} =1 and SK_{t-1} = 1, then Q_t^{DL} =1, which implies that $\alpha_0 = 0$.

The regression-results are as follows:

$$\ln Q_t^{DL} = \underset{(2.322)}{0.514} \ln HK_{t-1} + \underset{(2.420)}{0.526} \ln SK_{t-1}$$

$R^2 = 0.77$. t-statistics are given in parentheses. Thus,

$\alpha_0 = 0$
$\alpha_1 = 0.514$
$\alpha_2 = 0.526$.

(ii) Labor supply: The quantity of labor new graduates of vocational schools are able to supply is not quite dependent on wages (which are left out of the labor supply function for this particular case); rather it is determined by the competences of the graduates (human capital) and the capacities of the social networks (social capital) which enable the graduates to find jobs. We assume that minimal human capital and minimal social capital induce minimal quantity supplied for labor, i.e., if HK_{t-1} =1 and SK_{t-1} = 1, then Q_t^{SL} =1, which implies that $\beta_0 = 0$. To measure the human capital and social capital elasticity of labor supply, we asked some labor market participants questions, the answers of which yielded the following: a 1% increase in human capital leads to about 0.833 % increase (on average) in the quantity supplied of labor. A 1% increase in social capital leads to about 0.333 % increase (on average) in the quantity supplied of labor. Thus,

$\beta_0 = 0$
$\beta_1 = 0.833$
$\beta_2 = 0.333$.

(iii) The coefficient of adjustment (k): For simplicity, we will assume that HK_{t+1} / HK_t is proportional to the ratio of demand to supply, and hence, $k = 1$.

Given the empirical values of the parameters obtained above, we get,

$\lambda_1 = 0.5+0.262i$
and
$\lambda_2 = 0.5-0.262i$.

With all the needed parameter values at hand, the intertemporal equilibrium human capital is:

$$HK^* = \exp \{0.54 + \sum_{j=0}^{\infty} 0.56^j \frac{\sin\theta(j+1)}{\sin\theta} z_{t-j} \}$$

For analytical convenience, we will carry out some of our analysis in terms of logarithmically transformed human capital, ln *HK,* rather than *HK*. Since ln function is an order-preserving transformation, analysis in terms of ln *HK* and *HK* will yield the same qualitative results; and the quantitative results could be transformed into one another. The expected value of the logarithmically transformed intertemporal equilibrium human capital is:

$$E\,(\ln HK^*) = 0.54 + \sum_{j=0}^{\infty} 0.56^j \frac{\sin\theta(j+1)}{\sin\theta} E(z_{t-j})$$

Since, by virtue of the assumptions about u_t, and v_t, $E(u_t) = 0$, and $E(v_t) = 0$,
$E(z_t) = E(u_t)-E(v_t) = 0$. Thus,
$E\,(\ln HK^*) = 0.54$.

In view of the logarithmically transformed human capital scale of ln1=0 to ln5 ≅ 1.60, an intertemporal equilibrium expected human capital of 0.54 is low. As proven in the appendix A, the logarithmically expressed low human capital is also stable over time in the particular sense that it has a stationary distribution with a constant mean and variance.

The low level of equilibrium expected human capital implies a low level of equilibrium expected employment, i.e., substituting $\ln HK^* = 0.54$, and $\ln SK_{t-1}^{\ avr} = 0.9$ into the $E(\ln Q_t^{DL})$, we get 0.75, which is low as well. This indicates a low human capital-low employment trap facing the vocational school graduates over time.

The following section will extend the model in this section so as to incorporate the effects of educational technology and undertake system dynamics simulations that will illustrate the extent to which educational technology could help avoid the trap in question.

4. Educational Technology: Simulations

We will extend the previous model by reformulating the demand equation so as to incorporate the effects of educational technology. One of the central channels through which the effects of educational technology become evident is the growth of workers' productivity. Let Φ represent the productivity growth rate. For the sake of simplicity, we will assume that demand for labor will increase in proportion to the growth of productivity over time, which is influenced by the rate of educational technology utilization over time.

We will represent the impact of the change in the rate of educational technology utilization on the productivity growth with the following equation.

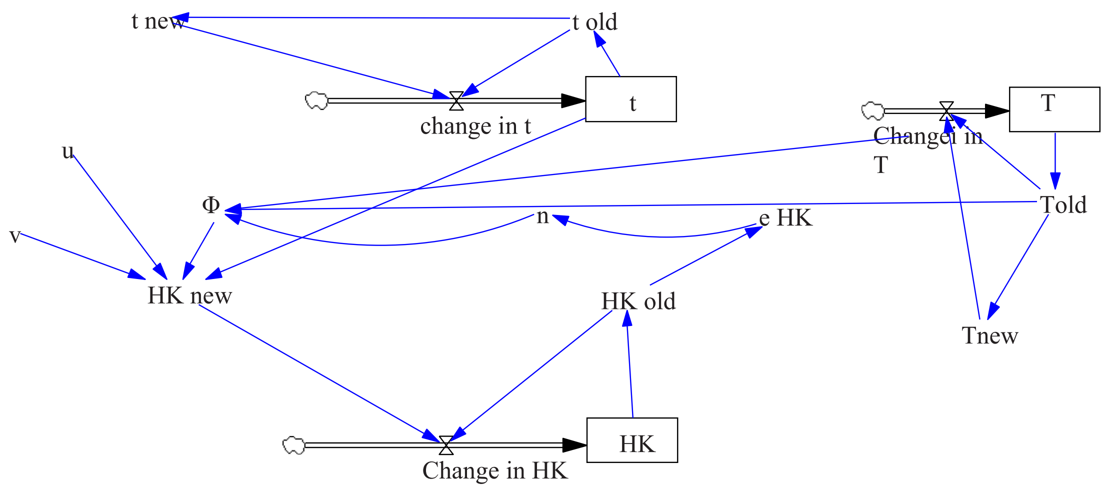
$\Phi = n.\ T_t$, where T_t is the rate of change of educational technology utilization at t.

The parameter, n, is required to satisfy the following properties: At low levels of human capital, the impact of T_t on productivity growth is high. As the level of human capital and educational technology utilization increase, advantages of technology utilization will be more and more appropriated and exhausted, and hence the impact on productivity growth will become smaller and smaller. These properties will be captured by the following equation.

$n = (\text{Maximum } HK_t - HK_t)/(\text{Maximum } HK_t\text{-Minimum } HK_t)$

We will measure the educational technology utilization on a Likert scale with 1 representing the lowest use and 5 representing the highest use. Using VENSIM, a system dynamics simulation software, we will model the equilibrium $Q_t^{DL} = Q_t^{SL}$, and simulate the effect, on human capital, of a 0.1 increase in the technology utilization in each period. The simulation diagram and simulation results are given below:

Simulation Diagram: HK represents human capital is in logarithmic form. e HK is human capital in the standard form.

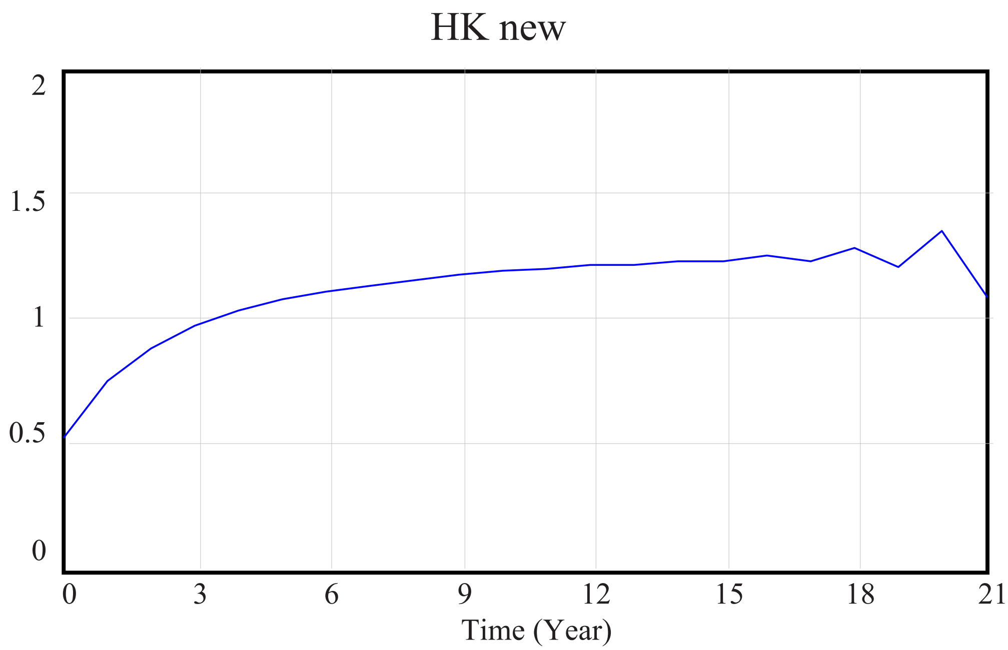


Simulation results

Time	"HK new"
0	0.539872 (0.54)
1	0.765487
2	0.901397
3	0.988229
4	1.04733
5	1.09152
6	1.12512
7	1.15074
8	1.17282
9	1.18941
10	1.20498
11	1.216
12	1.2289
13	1.23478
14	1.24851
15	1.24703
16	1.26792
17	1.24901
18	1.29702

19	1.22471
20	1.36881

Simulation graph: Graphical trajectory of human capital



A modest increase (0.1) in educational technology utilization in each period resulted in a considerable increase in human capital over time (i.e. from 0.54 to 1.36). Considering that the maximum value, in this study, of human capital in logarithmic terms is ln 5=1.6, the increase is quite significant. A simple calculation would reveal a considerable increase in the level of employment as well.

5. Concluding Remarks

The paper develops a labor market model of human capital and demonstrates the presence of a low human capital-low employment trap plaguing the vocational school graduates in Turkey. The paper explores an educational technology-based way out of the trap in question.

The extent to which the educational technology utilization could influence human capital and market outcomes points out the existence of a considerable potential for educational technology-centered improvements in real life processes. Explorations of particular ways in which educational technology could contribute to different sectors of economy in particular and different dimensions of economic and social life in general would be worthy of future research.

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